7.0 CONSTRUCTION MATERIALS AND INSTALLATION

7.1 GENERAL

This chapter discusses construction materials and installation guide for LFG recovery, treatment, and condensate management systems.

A primary consideration in determining suitable construction materials for LFG systems should be the compatibility of the construction materials with the LFG and condensate.

7.2 CONSTRUCTION MATERIALS

Construction materials discussed in this section include:

- gravel pack,
- cap and liner,
- piping material,
- valves and fittings, and
- blower and flare.
- LFG condensate

Combustion engines using LFG for energy recovery and the purification techniques to upgrade LFG to pipe line gas will not be discussed in this ETL as they are not likely applicable to the small landfills at most military installations.

7.2.1 Gravel Packs and Trenches

As discussed in previous sections, gas extraction wells, and collection trenches utilize gravel as the primary conveyance or as a pack around perforated collection pipes. Selection of the gravel material should be based on gas conductivity, grain size and pH.

A significant part of the system design should include the evaluation of the potential for granular materials to "sift" down into the waste pack. Where a high potential for the loss of granular material into the waste pack exists, a separation geotextile should be used.

Most clean, free-draining sands and gravels placed in a relatively dry condition function adequately for gas collection and conveyance purposes. As a general "rule-of-thumb," those soils which function best for LFG systems contain less than 6 percent by weight (74 microns or 0.0029 inches) passing the No. 200 sieve (U.S. Standard) and have a hydraulic conductivity coefficient (k) of greater than 10^{-3} cm/s. Soils which contain higher fractions of fines may function adequately during the initial phases of the operation, but experience has shown that these soils are more susceptible to clogging as a result of biological activity and saturation from the leachate.

Gravel packs installed with particle sizes which are too small tend to "sift" into the waste leaving either a void. Those with grain size distributions which are too large tend to entrain and accumulate fine particulate matter which can either clog the gravel pack or the filter fabric around the header.

Typically, gravel packs for wells and trenches have been sized using the procedures in the EPA's Manual of Water Well Construction Practices (EPA - 570/9-75-001), and USACE EM 1110-1-4001 Soil Vapor Extraction.

Although most sands and gravels are relatively inert in leachate and LFG condensate, some specific construction materials which pose potential compatibility problems should be avoided. For example, crushed limestone should not be used in LFG extraction wells or collection trenches systems due to LFG low pH conditions which may dissolve the lime stone.

7.2.2 Cap and Liner Systems

Historically, landfill caps and liners have been used principally to control the migration of leachate from the landfill. These cap and liners have typically consisted of natural geologic formations, compacted clay, geomembranes, and geosynthetic clays liners.

The purpose of the clay barrier layer in a composite cover (clay-geomembrane) is to inhibit the movement of gases and water which passes through holes in geomembrane. Soils used for clay barrier layer are selected to meet a specific conductivity requirement (typically 1 x10^{-7} cm/sec). If a clay liner is to be used for gas migration control, the designer should evaluate:

- clay permeabilities
- clay shrink-swell behavior
- water contents and saturation limits at the specified compaction densities
- operational schemes to determine the potential for desiccation drying

Geosynthetic clay liners (GCLs) are used to augment or replace compacted clay layers or geomembranes. GCLs are factory manufactured hydraulic barrier consisting of bentonite clay materials supported by geotextiles or geomembranes. GCLs are available in widths of 2.2 to 5.2 m (7 to 17 ft) and lengths of 30 to 60 m (100 to 200 ft).

Geomembrane liners are synthetic films placed along the bottoms, sides and caps of landfills to control leachate and gas migration. Typical liner materials consist of high density polyethylene (HDPE), very low density polyethylene (VLDPE), chlorinated polyethylene (CPE), chlorosulphanated polyethylene (Hypalon), polyvinyl chloride (PVC) butyl rubber and ethylene propylene rubber (EPDM). The thicknesses of these materials range from 20 to 120 mils, depending upon the application.

The most common types of geomembranes currently being used for landfill covers are PVC and very low density polyethylene (VLDPE). High density polyethylene (HDPE) is generally not used for landfill covers because it is less flexible than VLDPE making it more difficult to install and more susceptible to damage by differential settlement.

Detailed design procedures for cap and liner systems are provided in the EPA/625/4-89/022 "Requirements for Hazardous Waste Landfill Design, Construction and Closure", and EPA/625/4-91/0254 "Design and Construction of RCRA/CERCLA Final Covers." The Corps of Engineer Military Guide Specification 02271 "Geomembrane Barrier for Landfill Cover" should be used in contract documents when specifying geomembrane.

7.2.3 Piping and Header Materials

Two types of materials which have principally been used for gas transmission systems are steel and plastic. Because of its inferior corrosion resistance compared to plastic pipe, steel pipe is not recommended for use in LFG collection and conveyance Systems.

7.2.3.1 Plastic Piping

Plastic piping materials can be divided into two basic groups; thermoplastic plastics and thermosetting plastics (see Sections 7.2.3.2 and 7.2.3.3, respectively). When selecting the material to use, a number of factors should be considered. These include:

- durability;
- pipe strength; and
- dimensional stability.

Durability. The service life of a pipe material will depend on the durability of the material and the conditions under which it is exposed during service. The durability of a plastic depends on the polymer, the auxiliary compounding ingredients, the manufacturer and the installation of the product and it can vary greatly with respect to exposure conditions. The deterioration of plastics can take the form of:

- Softening and loss of physical properties due to polymer degradation by depolymerization;

- Stiffening or embrittlement due to loss of plasticizers resulting from repeated usage;

- Deterioration of mechanical properties due to swelling; and

- Failure of adhesive or heat fused joints due to interaction with condensate or leachate and physical stress.

These degradation modes are typically the result of repeated or prolonged physical stress, UV degradation, and chemical attack. Extensive research has been done on the chemical resistance of plastic pipe materials and numerous charts are available that give the relative resistance of a material to a specific chemical. Not as clearly understood, however, is the resistance of plastic materials to the mixtures of chemicals that may occur in the landfill environment. Research done by the EPA on plastic materials used for linings has shown that a wide variety of changes in physical properties can occur after exposure simulating service conditions. Among these are large weight gains (swelling) and loss of strength. The EPA Test Method 9090 may be used to estimate the degradation of specific pipe materials when exposed to site specific condensates.

Strength. Strength considerations for both PE and PVC (thermoplastic) pipes have been extensively researched and are well documented in manufacturers literature. Published strength characteristics are specified at certain temperatures. Actual service temperatures must be considered in designing the pipe system so that changes in strength characteristics due to elevated temperatures are considered in the material selected.

Property Changes. Changes in the physical properties of plastic pipe can be caused by various kinds of exposure to the outdoor environment. Weather effects can be minimized or eliminated by the proper storage and installation of the pipe. Materials not protected from UV radiation with the addition of carbon black should be protected both during storage and in service to prevent degradation.

All materials change dimension as a result of temperature changes. PE and PVC differ greatly in their respective changes in size as temperature changes. PVC has a thermal expansion coefficient of $3x10^{-5}$ in/in per ^{0}F of temperature change. PE pipe is three times higher or $9x10^{-5}$ in/in per °F. In a buried environment, where the temperature fluctuations should be minimal and the pipe is supported on all sides by soil, thermal expansion is of less concern. However, in systems where the collector pipes are above ground, thermal expansion and contraction must be considered in the design.

7.2.3.2 Thermoplastic Materials

Types of thermoplastic pipes include acrylonitrile-butadiene-styrene (ABS), cellulose acetate butyrate (CAB), polybutylene (PB), polyethylene (PE), and polyvinyl chloride (PVC).

ABS and CAB are materials that were used in natural gas transmission during the 1940s but are very rarely used today. PB has not found much acceptance for use because of inferior physical performance as compared to PE or PVC. PVC and PE are the most common types of thermoplastic pipe materials used. A survey conducted by the Governmental Refuse Composting and Disposal Association (GRCDA), now named Solid Waste Association of North America (SWANA), about LFG collection systems found that PVC and PE accounted for 97.7 percent (72.7 percent PVC, 25 percent PE) of the material used in the horizontal collector pipes and 95.4 percent (88.6 percent PVC, 6.8 percent PE) of the materials used in the vertical well pipes. PVC and PE are discussed further below.

PVC. PVC is produced by refining petroleum into naphtha, then to ethylene. Ethylene and chlorine are then combined to form vinyl chloride which reacts with a catalyst to form PVC. The PVC resin (or powder) is then mixed with a variety of additives to form the desired specific formulation of PVC required. The additives can include pigments, lubricants, stabilizers, and modifiers. The amount and types of these additives have a significant effect on the final PVC product. PVC formulations used for piping purposes contain no plasticizers and little of the other ingredients mentioned. These are known as rigid PVCs and are differentiated from the plasticized, or flexible PVCs such as those used to make upholstery or luggage.

PVC pipe sizes may be specified by schedule class or Standard Dimension Ratio (SDR). The SDR is the ratio of the pipe diameter to the wall thickness. Schedule 40 is a thin-wall pipe and cannot be threaded. Schedule 80 PVC pipe may be threaded and is used for more severe applications at higher working pressures. Standards for PVC pipe are given in ASTM D1785 for Schedules 40, 80 and 120.

PVC in general can be joined by adhesives, heat, or mechanical methods. Rigid PVC pipe is usually joined by epoxy adhesives. There are specific types of adhesives recommended for use with both Schedule 40 and 80 pipe and one must be careful to use the appropriate type. Standard specifications for PVC pipe can be found in ASTM D2564. In addition, because PVC is degraded by sunlight, above ground collection piping should, therefore, specify UV resistant material.

Polyethylene (PE): PE pipe is made from High Density Polyethylene (HDPE). HDPE is a thermoplastic material polymerized from ethylene at controlled temperatures and low pressures.

HDPE materials are generally divided into two density ranges: 0.941 through 0.959 and 0.960 through 0.963. The types of PE pipe used in the LFG industry fall into the lower density category. This lower density results in an improvement in impact resistance, environmental stress crack resistance, and flexibility.

PE pipe is classified according to ASTM D 2513, which employs a four digit material designation code. This specification defines the polyethylene pipe types most familiar to those in the LFG industry - e.g. PE 3408. Because of the wide variety of polyethylene pipe materials used today, an additional ASTM standard (D 3350) was developed to augment ASTM D 2513.

PE pipe must be joined by heat methods. Pipe segments and fittings are fused to one another at temperatures of approximately 230^{0}C (450^{0}F). Different thicknesses and types of pipe require different temperatures. There is no known suitable adhesive for polyethylene.

7.2.3.3 Thermosetting Plastics

Pipe used in LFG collection in this category is known as fiberglass reinforced plastic (FRP) orreinforced epoxy resin pipe. The pipe is generally translucent, with fibers imbedded in an epoxy matrix. The exterior has a more uneven finish than either PE or PVC pipe, but the interior is very smooth. The reinforcement in this pipe consists of continuous strands of glass. The direction and density of the glass affect the physical strength properties of the pipe. FRP pipe is typically joined by epoxy adhesives or mechanical connections. Threaded joining systems are also available. The use of this type of pipe in LFG collection systems has been limited due to the cost of the materials. It has, however, been used in both vertical wells and horizontal collector pipes.

The advantages of using FRP pipe in LFG collection include:

- high strength and durability;
- better resistance for melting at high temperature;
- corrosion resistant; and
- do not fail at low temperature.

The disadvantage of this material is high cost.

7.2.4 Valves, Fittings, Etc.

Valves used in the LFG control management include: globe valves, butterfly valves, gate valves, check valves, sample valves (labcock) and relief valves. The following considerations should be given when selecting valves:

- The type of service required. For example, globe valves can more accurately "pinch" or control a flow rate in gas or multi-phase service than butterfly valves; butterfly valves can more accurately control a flow rate in gas or multi-phase service than gate valves.

- Gate valves are used only to open or close the flow;

- Check valves are used to allow flow in one direction only;

- The corrosive properties of the gas. (discussed in the previous section.)

- The likely temperature conditions at an exposed site. PVC valves are prone to failure at low temperatures, therefore, lined metal or HDPE valves are preferable for cold-weather service.

- The strength and durability of the internal components. Because LFG systems consist of multi-phase flow, valves and fittings should be constructed of stronger and more durable materials than might normally be required in single phase water or gas service. The condensate can often form slugs of water drawn through the system at relatively high speed. This can result in a "water hammer" or impact loading on the valves and fittings.

The selection and layout of valves in the LFG system should be carefully evaluated during the project's review process to ensure that the level of control provided in the systems is consistent with projected O&M needs. A summary of valve applications on a typical active LFG collection system is presented in Table A-8.

7.2.5 Conduit Seals

Conduit seals are very important to prevent the migration of LFG through the electric conduit system. Where fugitive emissions or project cleanliness is a concern, gaskets or seals may be required on fittings, flanges and valves. Conduit seals should be located on underground conduits between the ground surface and panels or equipment where sparking components are located.

A wide variety of sealing materials is available; each with its own advantages and disadvantages. These sealing materials should be carefully evaluated for the specific application. Industrial plastics are the primary class of materials used for LFG applications. Table A-9 summarizes a comparison of various plastics and elastomers used for pipeline, fittings, valves, and seals as prepared by Fisher (1989). For additional information on these products, refer to the Industrial Plastic Systems Engineering Handbook by George Fisher (1989).

TABLE A-8

Summary of Plastic Materials Used for LFG Applications

Material	Abrv.	General Chemical Resistance	Maximum Permissible Water Temperature °C	
			Constant	**Short Term**
Polyvinyl Chloride	PVC	Resistant to most solutions of acids, alkalis and salts and to organic compounds miscible with water. Not resistant to aromatic and chlorinated hydrocarbons.	60	60
Chlorinated Polyvinyl Chloride	CPVC	Similar to PVC but at temperatures up to 90°C.	90	110
High Density Polyethylene	HDPE	Resistant to most solutions of acids, alkalis and salts many organic solvents. Unsuitable for concentrated oxidizing acids.	60	80
Polypropylene, heat stabilized	PP	Similar to HDPE but suitable for higher temperatures.	90	110
Polyvinylidene Fluoride	PVDF SYGEF ®	Resistant to acids, solutions of salts, aliphatic, aromatic and chlorinated hydro-carbons, alcohols and halogens. Conditionally suitable for ketones, esters, ethers, organic bases and alkaline solutions.	140	150
Polybutylene-1	PB	Similar to HDPE but for higher temperatures.	90	100
Polyoxymethylene	POM	Resistant to most solvents and hydrous alkalis. Unsuitable for acids.	60	80
Polytetrafluoroethylene (e.g. Teflon®)	PTFE	Resistant to most chemicals	250	300
Nitrile Rubber	NBR	Good resistance to oil and petrol. Unsuitable for oxidizing media.	90	120
Butyl Rubber Ethylene Propylene Rubber	BR EPDM	Good resistance to ozone and weather. Suitable for many aggressive chemicals. Unsuitable for oils and fats.	90	120
Chloropene Rubber (e.g. Neoprene®)	CR	Chemical resistance similar to PVC and between that of Nitrile and Butyl Rubber.	80	110
Fluorine Rubber (e.g. Viton®)	FPM	Has best chemical resistance to solvents of all elastomers.	150	200
Chlorine Sulfonyl Poly-ethylene (e.g. Hypalon®)	CSM	Chemical resistance similar to that of EPDM.	100	140
Perfluoro (ethylene-propylene) copolymer	FEP	Resistant to most chemicals, some strong acids will oxidize at high temp. and pressure.	205	220
Perfluoroalkoxy	PFA	Similar to FEP but with higher temperatures.	260	280
Ethylene/Chlorotrifluoro-ethylene copolymer	ETCFE Halar®	Good resistance to stress cracking in contact with alkaline and chlorine	180	200

TABLE A-9

Summary of Valve Applications

Valve Types	Applications	Advantages/ Disadvantages	Construction Materials
Gate valves	Duty: Stopping and starting flow. Infrequent operation Service: Gases/Liquids Vacuum/Cryogenic	Used only when the pressure drop through the valve is minimal	Carbon steel Ductile iron Cast iron PVC Plastic Austenitic Stainless Steel
Plug Valves	Duty: Stopping and starting flow. Moderate throttling. Flow diversion Service: Gases/Liquids/Vacuum Non-abrasive slurries Abrasive slurries used lubricated plug valve.	Minimum of space Simple operation Ease of actuation and tight shutoff	Carbon steel Ductile iron Cast iron Bronze PVC Plastic Austenitic Stainless Steel
Ball Valves	Duty: Stopping and starting flow. Moderate throttling. Flow diversion Service: Gases/Liquids. Vacuum/Cryogenic Non-abrasive slurries Most effective when fully open or closed.	Offer quick operation that is self sealing, and tight shutoff	Carbon steel Ductile iron Cast iron Bronze PVC Plastic Austenitic Stainless Steel
Globe Valves	Duty: Used to control (throttle) flow. Stopping and starting flow. Frequent valve operation. Service: Gas/Liquids essential free of solids. Vacuum/Cryogenic	Resistance increases when the direction of fluid flow through these valves changes	Carbon steel Ductile iron Cast iron PVC Plastic Austenitic Stainless Steel

TABLE A-9

Summary of Valve Applications

Valve Types	Applications	Advantages/ Disadvantages	Construction Materials
Check Valves	Duty: Open with forward flow Close against reverse flow. Service: Generally used with gate valves because of similar flow characteristics. Is required in a secondary system in which the pressure can rise above that of the primary system.	Offer quick automatic reactions to flow changes. Swing check valves offer minimum resistance to flow	Carbon steel Ductile iron Cast iron PVC Plastic Austenitic Stainless Steel
Butterfly Valves	Duty: Used to control (throttle) flow. Stopping and starting flow. Service: Gases/Liquids/Vacuum. Powder/Granules/Slurries Used for larger throttling valves	Initial low cost. Ease of installation and actuation.	Carbon steel Ductile iron Cast iron, PVC plastic Plastomeric materials for high temperature and corrosion resistance.
Three-Way Valves	Duty: Used to change flow direction Stopping and starting flow. Service: Gases/Liquids/Vacuum. Used on condensate tank to drain or to release vacuum.	Offer quick reactions to flow changes and tight shutoff. Ease of installation	Carbon steel Ductile iron Cast iron, PVC plastic Plastomeric materials for high temperature and corrosion resistance.
Sample Valves	Duty: Stopping and starting flow. Service: Used to take samples on a pipe/tank or on a gas well Gases/Liquids Pressure/Vacuum	Initial low cost Ease of installation	Carbon steel Ductile iron PVC Bronze Plastomeric materials for high temperature and corrosion resistance.

Source: Adapted from "Valve Selection Handbook, 2nd Edition", R.W. Zappe

7.2.6 Blowers

Section 4.4.3.2 discusses types and applications of blowers for LFG management. This chapter discusses the construction material of the blowers applied to LFG service.

Since LFG may contain particulates and aqueous vapor such as H_2S which is corrosive, a protective coating should be applied to all blower parts in contact with the LFG.

Experience with centrifugal blowers utilized in LFG collection has shown that cast aluminum impellers coated with a baked phenolic coating have been used with success against the corrosion effects of H_2S and of most other chemicals[(22)]. Stainless steel impellers without coating can be used, but the cost is very high.

Non-sparking impellers are recommended in centrifugal blowers to prevent gas ignition problems within the blower should an impeller contact the casing as the result of a bearing failure.

Ball bearings should be made with friction-resistant material, and designed to Antifriction Bearing Manufacturing Association AFBMA 9 and AFBMA 11 standards for a calculated life expectancy of 200,000 hours.

To absorb vibration during operation, flexible connections should be provided on both inlet and outlet sides of the blower. Since the LFG may be explosive, the blower motor should be explosion-proof and suitable for Class I, Division I, Group D, Hazardous Locations. Motor Code is discussed in Section 4.

7.2.7 Flare

The following materials can be specified for flare components:

Burner:

- 304L or 316L stainless steel;
- special nickel alloys, such as monel, inconel, hastelloy;
- venturi liners should be castable refractory, and

- should have temperature rating at 2700^{0}F.

Flare Stack:

- shell material is made of 3/8"thick ASTM A36 carbon steel with exterior and interior coatings for corrosion resistance;
- ceramic fiber for insulation materials; and
- The allowable radiation to meet specific needs (unattended station or location where personnel may need to perform work for a short period of time);

Flare Tip:

- flare tip (upper section of the flare) should be made of high temperature stainless steel (304L or 316L) materials.
- the tip size to meet the velocity requirements of Federal Regulations 40CFR 60.18.

Flame Arrestor:

- arrestor element can be aluminum or 316 Stainless steel;
- element housing can be welded steel or 316 Stainless steel.

In general, the selection of construction materials for flares is based on the size, service life, and material and fabrication cost. Manufacturer consultation is recommended for selection of construction materials for flares because the cost of materials, fabrication, and machining as well as service life may vary significantly.

7.2.8 LFG Condensate

An important design consideration for LFG condensate treatment systems is to prevent condensate as much as possible. Because LFG condensate is very corrosive, avoid to use carbon steel where aqueous phases may occur. HDPE and FRP are suitable materials for condensate collection at atmospheric pressure. When carbon steel components are required in services with the potential for exposure to low pressures (less than 70 KPa), exposed steel parts should be coated with corrosion resistant plastics. Exposed steel parts subjected to higher pressures should be coated with zinc or corrosion resistant epoxies.

7.2.8.1 Combustion Engines

Experience has proven that combustion engine parts most frequently susceptible to corrosion or wear are exhaust valves, valve guides and stems. The service life of these components can be notably increased by chrome plating or other surface hardening.

Turbine manufacturers strongly recommended that fuel gas compressor oil and condensate carryover be prevented from entering the engine and combustion system.

7.3 INSTALLATION CONSIDERATIONS

Installation considerations will include the following:

- Gas Well/Trench installation;
- Header Pipe Installation;
- Condensate tank and pumps installation;
- Blower installation; and
- Flares installation.

7.3.1 Gas Wells and Trenches

Wells:

Wells are connected to a collection system that carries the gas to the treatment or energy recovery system. The wells must be individually valved so the vacuum applied to each well can be regulated. Pipe diameters will be determined by the gas flow rate and the need to minimize pressure losses. In addition to requirements described in the previous Section 4.4.2, the regulated. Pipe diameters will be determined by the gas flow rate and the need to minimize pressure losses. In addition to requirements described in the previous Section 4.4.2, the following standards should be used for installation of LFG extraction wells:

- ASTM D5092 - Practice for Design and Installation of Groundwater Monitoring Wells in Aquifer,
- AWWA AlOO - Water Wells,
- USEPA 570/9-75/001 - Manual of Water Well Construction Practices.
- ASTM D F80 - Thermoplastic well casing pipe/couplings made in standard dimension ratios (SDR) schedule 40/80, specification,

Trenches:
The following requirements should be considered for trench installation:

- Correct depth and width of the trench;
- slope of the trench (minimum 2 percent);
- distance between trench (vertical and horizontal),
- gravel-pack base installation;
- liner cover material;
- compaction method;
- pipe joints (following pipe manufacturer's recommendations), and
- cap seal (following geomembrane manufacturer's recommendations).

Some of these requirements are described in the previous Section 4.4.1.2, Trench Collection Systems.

7.3.2 Header Pipes

The following considerations should be used for the installation of LFG-header collection system. Some of these requirements are described in the previous Section 4.4.3.1.

Header Underground:

- excavation elevation, slope,
- gravel bedding placement,
- location and size of header pipe,
- pipe slope to have a minimum 2 percent,
- condensate traps should be at lowest point
- placement of magnetic detection tape to locate pipe by metal detector,
- placement of screened gravel in excavation,

Header Aboveground:

- pipe location;
- pipe slope (minimum 2 percent);
- condensate traps location (at lowest point)
- provisions for thermal expansion/contraction;
- pipe support;
- seal joint or seal connection repair, and
- pipe insulation to keep LFG temperature above dew point.

It is usually preferable to lay the pipe work below ground; above-ground pipes, which require protection from the ultraviolet rays of sunlight, are typically used only on a temporary basis while settlement is taking place. Pipe joints should be minimized. The joints should be sound, with positive seals, and flexible enough to compensate for movement caused by settlement and temperature variations.

7.3.3 Condensate Management

Followings are considerations for the installation of condensate collection system:

- condensate tank location;
- excavation depth, if below grade;
- gravel bed placement for the condensate tank foundation;
- pipe and fitting connections;
- condensate pump installation; and
- Condensate treatment, if required.

Because of the potential for "slugs" of condensate to form in the collection network, valves, fittings, elbows, and control devices should be securely anchored to avoid damage from the water-hammer effects which can result as these "slugs" of water are drawn through the system.

7.3.4 Blower

Followings are considerations for the blower installation:

- blower location;
- foundation plan meeting blower design loads;
- pipe connection;
- noise deflector, if required;
- flame arrestor location; and
- Electrical and control system installation.

The blower should be installed in a shed at an elevation slightly higher than the end of the header pipe to facilitate condensate dripping. For blower motors with horsepowers of 5 or more, a three-phase electrical connection is usually required.

7.3.5 Flare and Appurtenance Installation

In addition to the requirements described in the previous Section 4.4.4.1, the following design parameters should be considered for the flare and appurtenance installation:

- flare location,
- foundations plans meeting design loads,
- fuel-assisted equipment location,
- ladder and safety cage installation,
- location of water seal,
- location of flame arrestor, and installation of temperature controller.